

# Design and Analysis Fixtures for Aluminium Die Casting Component

B.Maharajan, Dr.S.Balasubramanian

**Abstract**– Fixture in tooling industry contributes more to improve economy of production. It ensures quality and quick transition of parts. A novel design on a fixture for tapping holes for complicated profile petrol pump body made of aluminium die casting material. The fabricated fixture used for trials. The time study conducted with samples and the results we compared with manual cycle time. Improvement in reduced cycle time shown 50% and the rejection quantity due to unthreaded threads, shifting of axis and end damage are reduced 1/50 batch. Fixtures like this can adopt to the mass production components in automobile, Aeronautics and manufacturing units.

**Keywords:** fixtures, aluminium, tapping, production

## I. INTRODUCTION

Engineering components produced in manufacturing industry are assured for quality issues. In metal removing process the work piece to be hold firmly on the bed of machine. The fixture plays a vital role to fix quality, quantity and cost in production.

Fixtures are used to hold the work piece during machining operations. The name is derived from the fact that a fixture is always fixed or fastened to a machine in the fixed position. It does arrangements for support jig and guiding the tool. The use of fixture becomes essential. When the components to be produced are in large number.

There are many number of fixtures used in different industries for different types of work pieces. But generally they are classified on the basis of their working operations in different machine tools. In a setup using a fixture the responsibility for accuracy depends upon the operator and the construction of the machine tool.

Here we are design a fixture for tapping operation on casted holes. The operation of tapping is done in a drilling machine with gang tapping attachment. Here the body of the petrol pump made of aluminium casting has six drilled holes; manually it is made by six times of moving and setting the tool. The non fixture takes 1/6<sup>th</sup> of time of manual.

### A. Steps of fixture design

Fixture design begins with a successful logic and systematic plan. Fixture functional requirements with a complete analysis, it occurs very few design problem.

**Manuscript Received July 18, 2017**

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The workpiece tooling, processing and machine tool may affect the extent planning needed. Preliminary analysis may take from a few hours up to several days for more complicated fixture designs. Fixture design can be done in five steps for problem solving process.

### Step.1 Define requirement

To initiate the fixture design process, state the problem clearly to be solved. State these requirements as broadly as possible, but specifically enough to define Scope of the design project. The designer should ask some questions themselves that is the new tooling required first time production or improve existing production?

### Step.2 Gather / Analysis Information

Collect all relevant data and assemble it for evaluation. The main source of information are the part print, process sheet and machine specifications. Make sure that part documents and records are current. With these notes they should be able to fill in all items on the checklist for design considerations. All ideas, thoughts, observations and any other data about the part fixture are then available for later reference. It is always better to have too many ideas about the part or fixture are then are available for later considerations need to be taken into account. For design considerations need to be taken into account.

### Step.3 Develop Several Options

This of fixture design process requires the most creatively. A typical work piece can be located and clamped several different ways. The natural tendency is to think of one solution, then develop and refine it while blocking path right away. A designer should brainstorm for several good tooling alternatives, not just choose one path right away. During this phase the designers' goal should be adding options not discarding them. The more standard locating and clamping devices that a designer is familiar with the more creative. Areas for locating part include flat exterior surfaces.

### Step.4 Choose the Best Option

The total cost to manufacture a part is the sum of per piece run cost, setup cost, and tooling cost. Expressed as a formula:

$$\text{Cost per part} = \text{Run cost} + \frac{\text{Setup cost}}{\text{Lot size}} + \frac{\text{Tooling cost}}{\text{Total quality over tooling life time}}$$

### Step.5 Implement the design

The final phase of the fixture design process consists of turning the chosen design approach into

reality. Final details are decided, final drawings are made and the tooling is built and tested. The following guidelines should be considered during the final design process to make less costly while improving its efficiency.

## II. LITERATURE SURVEY

1. Shailesh S. Pachbhai, Laukik P. Raut (2014) have described that in machining fixtures, minimizing work piece deformation due to clamping and cutting forces is essential to maintain the machining accuracy. This can be achieved by selecting the optimal location of fixturing.
2. Chetankumar M. Patel, Dr. G. D. Acharya (2014) have discussed that Paper proves utility of hydraulics in fixture design in three different ways: (i) reduces cycle time, (ii) reduces operator fatigue and increases productivity and (iii) reduces wear and tear of fixture components.
3. In contrast to concentration of six axis nano positioning method Dr. Patrick J. Golden (2013) tested a unique dovetail fretting fatigue fixture was designed and evaluated for testing turbine engine materials at room or elevated temperatures. Initial test results revealed interesting variability in the behaviour of the nickel based super alloy specimens at elevated temperature.
4. K.C. Aw (2013) paper concentrates on electronic equipment used for maritime application. Simulation using ANSYS workbench software was performed to comprehend the effect of various parameters of accelerated testing performed on these waterproof enclosures. Experiments were performed to examine the correlation with simulation results. The above mentioned strategy was applied to reduce the buckling in a part of fixture design assembly.
5. T. Papastathisa, O. Bakker, S. Ratcheva, A. Popova (2012) have described that instead of using passive fixture element use active fixture element because it reduce the dynamic deformation of the work piece by 84.2%.
6. The study of Dr. Yu Zheng (2008) presents a method for finding form-closure locations with enhanced immobilization capability. Fixtures are used in many manufacturing processes to hold objects. Fixture layout design is to arrange fixturing elements on the object surface such that the object can be held in form-closure and totally immobilized.
7. The research of closure locations was determined experimentally by Kartik (2007) as it focused on the kinematics, stiffness, repeatability of a moving groove and dual-purpose positioned fixture. A dual-purpose positioned fixture is an alignment device that may be operated in a fixture mode or a six-axis nano-positioning mode..
8. Mervyn (2003) addresses the development of an Internet-enabled interactive fixture design system. A fixture design system should be able to transfer information with the various other systems to bring about a seamless product design and manufacturing environment. Thus a great amount of experience of fixture design is wasted and cannot be re-used, which reduces design efficiency and violates the t

intention of case-based reasoning methods. In order to realize agility of fixture design, including re-configurability, re-scalability and re-usability.

Many of the researchers done a fixture for variety of methods such as welding, turning, drilling, honing, assembly etc, except tapping for mass production components. We proposed a special fixture for gang tapping of aluminium components.

## III. PROBLEM FORMULATION

The problem related to reduction of time in production in tapping operation will be discussed in detail is given below.

- The main problem to reduce the time in mass production.
- To reduce the number of stroke of the tool moving.
- To reduce the setting time according to the worker skill.
- To improve the quality of the product.
- To reduce the rejection quantity of the product.
- To reduce the loading and unloading time.
- Here the industry faces lot of problem for handling the aluminium component for tapping.
- The company has faced more problems in production to give good quality products and to minimize the rejection of quality.

So to overcome these problems, it is proposed and design develops a fixture which will possibly reduce the entire problem.

## IV. DESIGN DETAILS

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### A. PROCEDURE

Most of the components undergo same design procedure. The design procedure used for designing the part components are as follows:

- **Side plate** has been cut according to the dimension required (180\*150).
- Holes are made at the left and right side at the middle of the plate of dimension (108).
- Right side holes are made in order to hold the plate using clamping operation. Respectively e holes on the left side. Locking pins are provided in order to avoid the shaking of the work piece.

- Bottom plates are provided to join the side plate by using bolt.
- **Shaft** consist of two holes at one end and on the other end a U shape has been designed.
- **Component Holder** is designed using extrude and cut operation through which a component can be hold easily.
- **Stud** has been designed using solid work for the required dimensions. Cuts are provided by using cut operation.
- **Locking pin** is designed in the shape of a T block.
- **Bolt** is designed as the locking pin but in addition thread is provided.
- **Nut** is designed with internal thread.

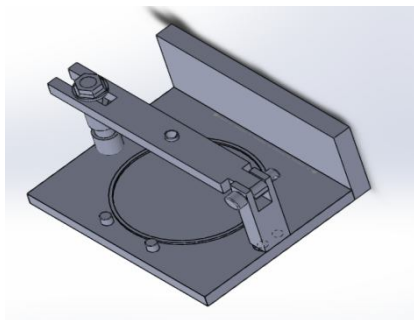


Fig.1: Assembled fixture

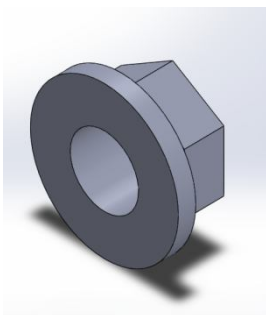


Fig.2: Nut

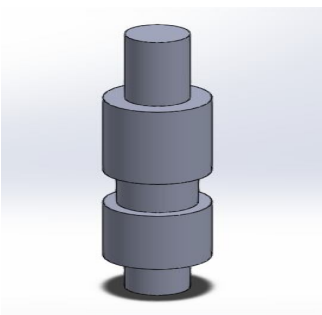


Fig.3: Stud



Fig.4: Bolt

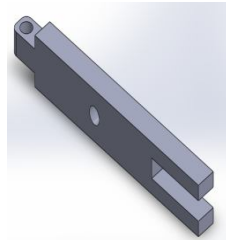


Fig.5: Component Holder

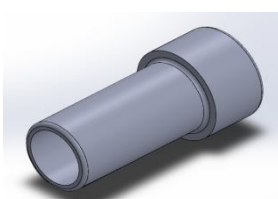


Fig.6: Locking Pin

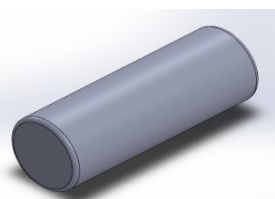


Fig.7: Locking pin

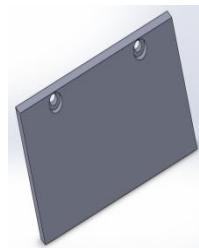


Fig.8: Side Plate



Fig.9: Main Plate

## V. COMPONENT DETAILS

In industries tapping fixture is manufactured according to application requirement. For this fixture all input data explained in above design procedure is collected. AISI140 material is selected for design. Side plate, bottom plate, holder, component holder, locking pin, lockets pin, stud and nut. The component located on the side plate on the side plate with reference of 90mm diameter on the body is shown in fig.14. For steadiness it is clamped at centre with a nut.

The tapping fixture is shown in below figure. The fixture is look like 'L' shape structure. It consist of side plate which was machined a groove for a component to seat at the area and it was also hardened to reduce the wear and to produce large number of quantity. Here we can arrest the component with the bottom plate to reduce vibration and it can be locked with the holder, component holder, locking pin, stud and nut. In the second operation tilt the 'L' shape fixture for tapping the final two holes. The assembly drawing of a fixture is shown in fig.15.



Fig.10: Aluminium body



Fig.11: Assembly of fixture

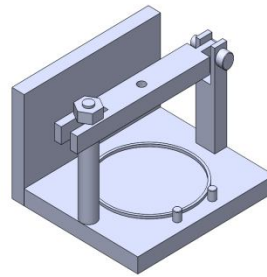


## VI TESTING

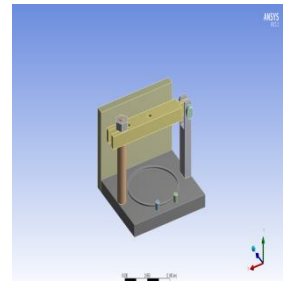
<b>Mitutoyo</b>		Protocol number (0)	
User name Admin		Part name METER COVER MANUAL F	
01.04.2017 12:49			
PART NAME METER COVER		SHIFT/BUNK NO T20120 MANUAL FIXTISI	
El. Line Element		OPERATOR / INSPECTOR NAME A. PARTHIBAN	
No. No.	Tolerance	Ref. Nominal	Diameter Dist./Ang. Dev./Error
1 5 PLANE- Mean	10	0.001	44.502 0.003
1 9 Line Mean	4	89.998 90.000	0.002
1 13 CIRCLE- Mean	6	368.751 -1.339 90.000	366.754 0.015
1 16 CIRCLE- Diameter	6	90.209 179.791 90.000	108.608 0.062
1 17 Line-1 Mean	4	-277.335 93.700 15.583	108.608 0.062
2 20 Line-1 Perpendicularity	4	108.250 -0.050 0.000	0.358 0.002
2 21 PLANE- Mean	4	-1.307 170.018 90.000	170.023 0.002
2 24 PLANE- Flatness	4	179.500 90.440 90.000	0.685 0.002
3 25 PLANE- FACE Mean	4	-0.638 83.220 91.015	0.001
3 26 PLANE- FACE Parallelism	4	90.296 47.862 42.439	0.738 0.000
1 29 REF	1	-0.071 0.078 18.354	0.748 0.000
		90.221 89.756 0.329	
		-284.007 153.737 16.676	

The above dimensions are within the limits and hence the fixture can be used for production process.

GEOPAK CMM Scan made in MCOSMOS Manual v3.5.16  
- Page 1 -



CAD Model



ANSYS Imported Image

## VII RESULTS

### LOADS APPLIED – TYPE 1

Table 3. Experimental values of axial thrust,  $P$  measured at 167 RPM for different diameter drills and work materials

S. No.	Drill Dia. (in mm)	Axial thrust, $P$ (in N) for different work materials				
		Brass	Alum-inium	Cast iron	Mild steel	Copper
1	12.0	774.1	877.2	1032.0	1651.5	1033.2
2	11.0	748.3	877.2	980.5	1393.4	1032.2
3	10.2	722.5	722.3	980.5	1238.6	980.6
4	9.0	567.6	619.3	825.8	1135.3	877.2
5	8.0	516.1	619.2	774.2	1083.8	774.1
6	7.0	516.1	567.6	774.1	1083.8	774.1

Table 4. Experimental values of torque,  $M$  measured at 167 RPM for different diameter drills and work materials

S. No.	Drill Dia. (in mm)	Torque, $M$ (in N-m) for different work materials				
		Brass	Alum-inium	Cast iron	Mild steel	Copper
1	12.0	3.381	3.651	3.654	6.840	6.086
2	11.0	2.705	2.840	2.840	6.086	5.680
3	10.2	2.029	2.840	2.651	6.086	5.410
4	9.0	2.029	2.028	2.434	5.680	5.086
5	8.0	1.217	1.623	2.246	5.275	4.733
6	7.0	0.811	1.623	1.840	4.057	4.056

Load Values Taken\_ From Journals- Reference Loads

Drill Dia= 12.0

Torque = 6.840

Material = MS

Force = 1651.5 N

Applied Load = 3 Times of Actual Force = 5000 N (Rounded)

Applied Torque = 3 Times of Actual Torque = 21 N-m (Rounded)

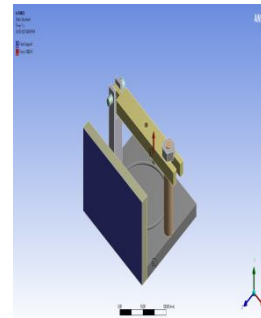


Fig.12 Boundary Conditions  
Base Face and Side Face are Fixed Force is Applied on the Under Face of the Clamp

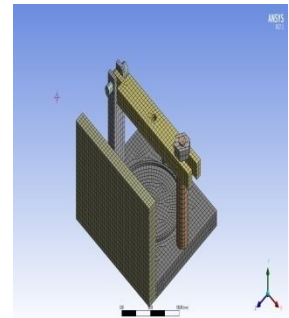


Fig.13 Meshed Model

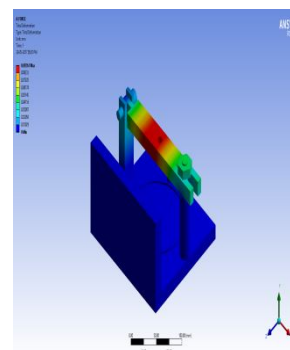


Fig.14: Total Deformation

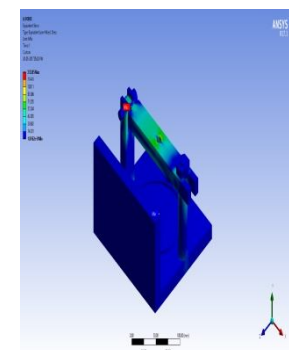


Fig.15: Stress Deformation

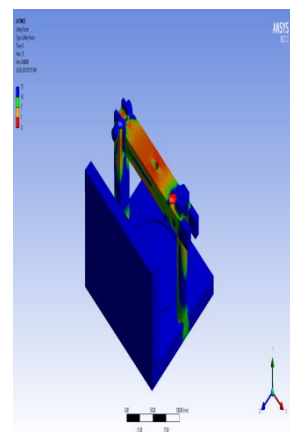


Fig.16: Overall FOS

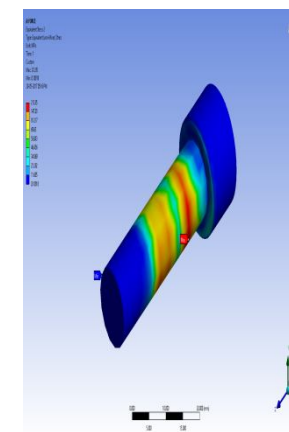


Fig.17: Stress in Pin

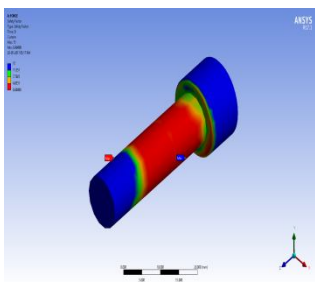


Fig.18: FOS in Pin

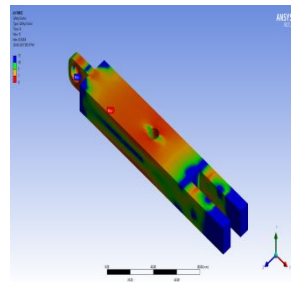


Fig.19: FOS in Clamp

#### Result Values \_ MIN / MAX

Total deformation 0 / 9.261e-002 mm  
Stress 1.8762e-008 MPa / 212.85 MPa  
Stress in pin 0.10818 MPa / 212.85 MPa  
FOS total 0.40498 / 15  
FOS in Pin 0.40498 / 15  
FOS in Clamp 0.55458 / 15

#### TYPE 1 – ROTATIONAL LOAD

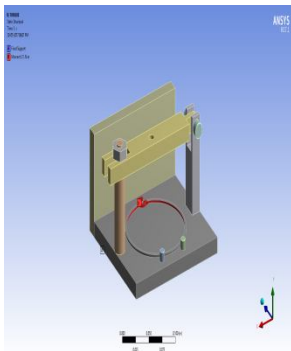


Fig.20:  
Torque applied  
On the Walls on the  
Butting Faces Results

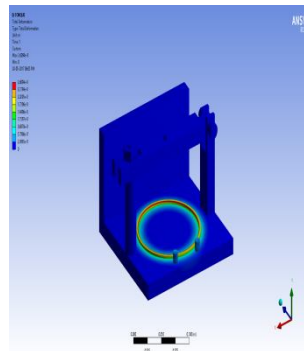


Fig.21:  
Total Deformation

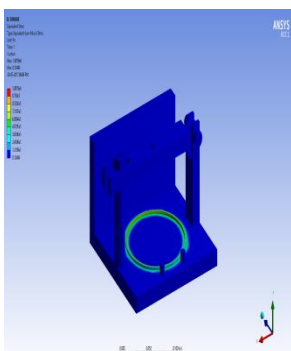


Fig.22: Stress

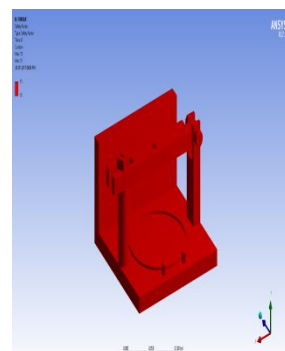


Fig.23: FOS

#### Results Values \_ MIN / MAX

Total deformation 0 / 2.6094e-008 m  
Stress 1.2494e-007 MPa / 1.0979 MPa  
FOS 15 / 15

#### TYPE 2 – IMAGE

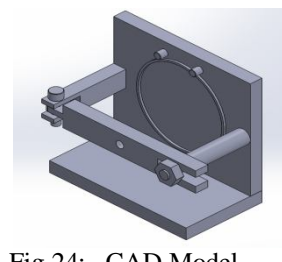


Fig.24: CAD Model

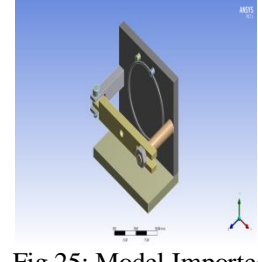


Fig.25: Model Imported  
into ANSYS

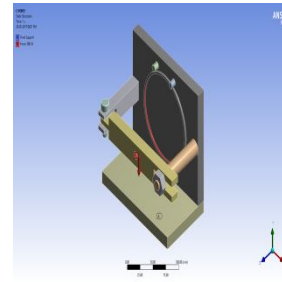


Fig. 26: Supports Bottom  
Face – Fixed Loads Applied  
on the Cylindrical Faces and  
Bolt Location

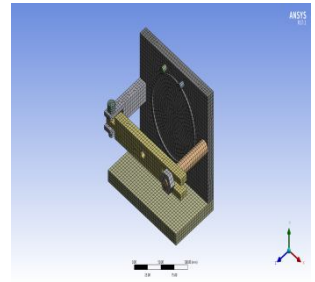


Fig.27 Meshed Model

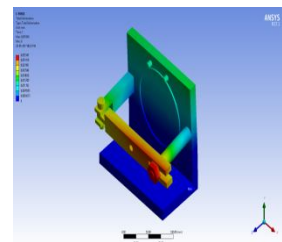


Fig.28 Total Deformation

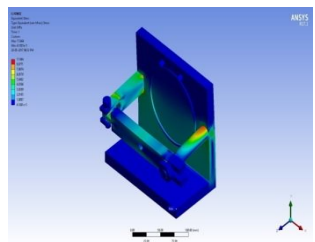


Fig.29 Stress

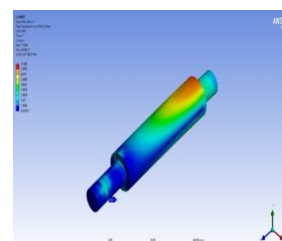


Fig.30 Stress in Locking Pillar

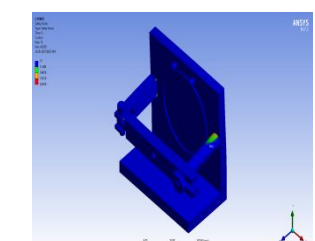


Fig 31 FOS Total

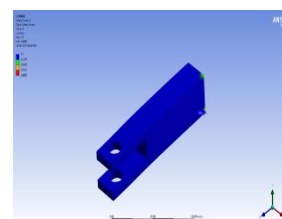


Fig.32 FOS – Clamp Location

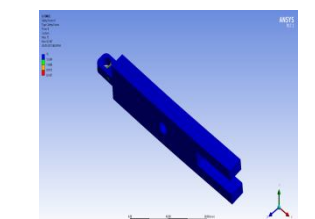


Fig.33 FOS - Clamp

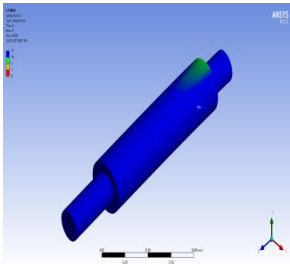


Fig.34 FOS – Locking Pillar

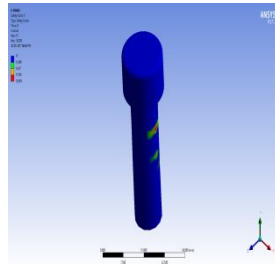


Fig.35 FOS on Clamp

#### Results – Values | MIN / MAX

<b>Total Deformation</b>	<b>0 / 3.5345e-002 mm</b>
<b>Stress</b>	<b>4.1081e-005 MPa / 17.464 MPa</b>
<b>Stress on Locking Pillar</b>	<b>7.0213e-00 MPa / 17.464 MPa</b>
<b>FOS – Total</b>	<b>4.9359 / 15</b>
<b>FOS – Clamp Pillar</b>	<b>6.6695 / 15</b>
<b>FOS – Locking Pillar</b>	<b>4.9359 / 15</b>
<b>FOS – Clamp</b>	<b>8.2167 / 15</b>
<b>FOS – Pin</b>	<b>10.939 / 15</b>

#### VIII. CYCLE TIME ESTIMATION

The design of fixtures should be such that the process of loading and unloading the components takes the minimum possible time and enables on easy loading. Here the fig.16& 17 showing the fixture in open and close position. The fig.18 shows the tapping operation – 1 and the fig.19 shows the tapping operation – 2. The fig.20 shows the cycle time for tapping by manual Vs fixture.

Table 1: Cycle time estimation

Operation	Manual	Fixture
Clamping time	10secs	5secs
Tapping time (6 holes/6 times)	60secs	
Tapping time (6 holes/3 times)		30secs
Unclamping time	10secs	5secs
Cleaning time	10secs	5secs
Total cycle time	90secs	45secs



Fig.36 Fixture in open clamp position



Fig. 37 Fixture in closed clamp position

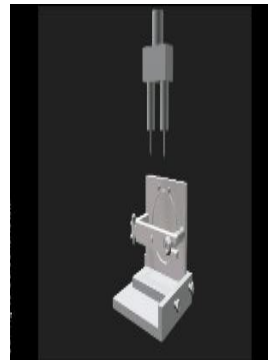


Fig.38  
Tapping operation-1



Fig.39  
Tapping operation -2

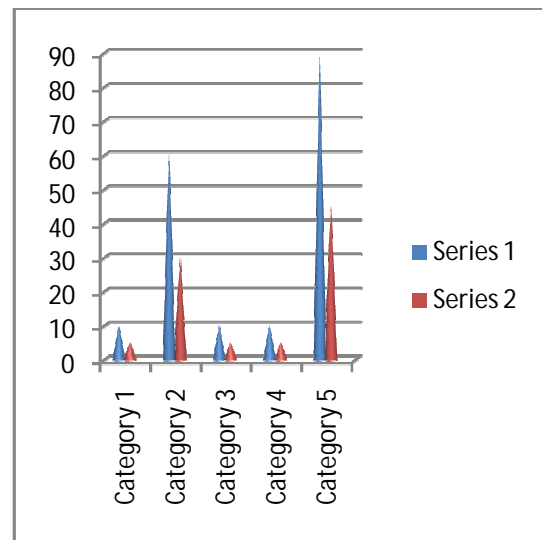


Fig.40: Cycle time for tapping by manual vs fixture.

#### IX. RESULTS AND DISCUSSION

The flexibility of fixtures plays an important role in reducing machining costs and times in manufacturing industries.

Fixture design explained in this paper can help to improve productivity and accuracy of machining significantly, lowering the time and skill level needed.

1. In the previous method tapping operation is manually done in six drill holes and put tap in by making setting for individual hole for six time. It is done by new fixture method called gang tapping fixture and the operation of tapping is done by three times.
2. Due to new tapping fixture are exactly located, supported and clamped which reduces the machine setting time, hence the productivity time increased by 50% and also increase in accuracy and process control.
3. In the previous method due to clamping aluminium component in vice can damage the body and the holes are not aligned as through holes and lot of piece may be rejected.
4. Rejection rate reduced to less than 2% in this fixture comparison to 15% of individual tapping, because new tapping fixture gives uniform clamping and reduced vibration.

5. For this new tapping fixture coolant oil (kerosene) is used to cooling the threaded area and to remove small metal particles of machining.
6. The rejection quantity due to unmatured threads, shifting of axis and end damage are reduced 1/50 batch.

## X. CONCLUSION

The efficiency and reliability of the fixture design has enhanced by the system and the result of the fixture design has made reasonable. To reduce cycle time required for loading and unloading of part, this approach is useful, SOLID WORKS are used in designing the systems then significant improvement can be assured. To fulfil the multifunctional and high performance fixturing requirements optimum design approach can be used to provide comprehensive analysis.

## XI. ACKNOWLEDGEMENT

We acknowledge Er. V. Satyamoorthy, Manager in Production M/s DOITER CASTINGS for providing facilities to fabricate and trial run of tapping operation.

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